Legal form and risk exposure in Spanish firms

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Abstract. It is well-known that the legal form adopted by a firm determines the type of legal responsibility borne by its owners in case of bankruptcy. In this paper we argue that a firm under a limited liability status should be characterized by a higher than average bankruptcy probability, which ultimately captures their risk exposure when output is affected by exogenous shocks. To test this prediction we extend Lee's (1976) switching regressions model to a panel dataset of 1313 Spanish firms from 1990–1994, separating them into corporate and entrepreneurial forms (with/without limited liability, respectively). We consider both random effects and fixed effects panel data models, taking into account the potential endogeneity between risk exposure and the legal form choice. Our results confirm the hypothesis that firms under limited liability have significant higher risk exposure than firms under unlimited liability.

JEL Classification: C20, G32, L21

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1 Introduction

Standard economic analysis often presumes that, in absence of relevant ownership-control conflicts, the ultimate aim of any firm's manager is to obtain the highest

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possible profit. This approach, which is usually simplified into a maximization problem with one or more constraints, ignores the fact that a firm's objective function is not entirely independent of its ownership structure. In this paper we intend to show that the firm's legal form entails relevant implications with respect to the assignment of the residual rents it generates and, consequently, modifies the incentives of the individuals involved in this maximization process, thus affecting their subsequent product or labor market decisions.

Our basic argument relies on the well-known relationship between the legal form adopted by a firm and the type of legal responsibility faced by its owners in case of financial distress (Jensen and Meckling 1976). When the owners are stockholders with limited liability over the residual rent, they are at risk for the firm's obligations only up to the amount of their initial investments. If some of the firm's financing is via debt (to be repaid before the owners get any return on their investments), they might prefer to make excessively risky decisions rather than maximize the value of the firm. If business performs well, debtors are paid their contracted amounts and equity holders retain the remainder. When things go badly, debt is not repaid in full since creditors can only claim property owned by the company. Some of the losses are thus shifted onto the debtors; riskier decisions shift more of the downside onto the debtors and always leave the upside gain to the stockholders.

There are different legal forms under which private business can be carried out. For example, as in most other countries, Spanish Corporate Law distinguishes between two main legal forms: one in which firms have no legal capacity separate from its owners (non-corporate, individual firms or sole proprietorships), and other in which firms do have this capacity (corporate firms or *societàrie* forms). Characteristic examples of the former are the sole proprietorship (*empresa individual*) and the collective association (*sociedad colectiva*), whereas corporate forms are mostly limited liability ones (particularly, the *sociedad anónima*, SA, and the *sociedad de responsabilidad limitada*, SL). The distinguishing features of all these different legal forms according to Spanish Corporate Law have been summarized in Table 1.

Since the pioneering work by Berle and Means (1932), a whole strand of the literature has related a firm's legal status with its observed real market performance. Most authors have extensively appealed to the agency theory to explain the relationship between the ownership structure of an organization and the way in which operating decisions are made inside.[1] We coincide with recent papers on corporate governance in the analysis of how changes in the ownership structure affect the firm's decisions (Shleifer and Vishny 1996), although they usually do not compare different legal forms, or relate the comparison to tax advantages (Mackie-Mason and Gordon 1997). We prefer instead a different path. We build a simple model for the 'limited liability effect' described above and test whether a distinct legal status

[1] See Demsetz (1983) for a summary of the debate. There also exists an extensive empirical literature relating the firms' real behavior with descriptive factors (such as size, R&D, productivity, foreign or public capital, etc.) including the legal form as one of the explanatory variables (see a recent survey in Demsetz and Villalonga 2001). Among the few ones with Spanish data that explicitly consider the type of ownership, it is worth mentioning Fariñas et al. (1992), Galvé and Salas (1993) and Merino and Salas (1995).

Table 1. Main characteristics of Spanish firms' legal forms

	Type	Liability	Capital requirements**	Partners	Other characteristics
Individual firms	Sole proprietorship (SP)	Unlimited	No upper or lower limit	1 (maximum)	Non-strict accounting procedures nor corporate governance mechanisms Full (personal) liability for the firm's debt and credits
Corporate firms*	Collective association (CA)	Unlimited	Ptas. 50 mill. (max.)	2–50 (maximum)	Non-strict accounting procedures nor corporate governance mechanims Participations are not tradable. Full (personal) liability
	Sociedad limitada (SA)	Limited	Ptas. 0,5 mill. (min.)	1 (minimum)	Strict accounting procedures and corporate governance mechanisms Participations are not tradable. A SL may change its legal form only to SA or CA
	Sociedad anónima (SA)	Limited	Ptas. 10 mill. (min)***	1 (minimum)	Strict accounting procedures and corporate governance mechanisms Shares are tradable. Any SA may change its legal form only to SL or CA

* There are other possible legal forms in Spain, but only apply to a fraction of firms (less than 2%) and correspondingly, to very specific economic circumstances.

** Currency equivalence: 1 million pesetas = 6010 Euro (approx.)

*** This limit was compulsory by June 30, 1992. All *sociedades anónimas* whose capital was below it were forced either to increase their capital or to become a SL or a CA.

(firms with/without limited liability) affects the level of risk exposure to bankruptcy, measured through the choice of a capital-labor ratio for a given amount of debt when the output is affected by exogenous shocks on productivity.

This analysis contributes to the literature on the limited liability effect started with a seminal paper by Brander and Lewis (1986), and later extended by Glazer (1994), Showalter (1995), Maksimovic (1995) and, more recently, Faure-Grimaud (2000). They all show that the limited liability confers some strategic effects to debt and may ultimately affect competition in prices, quantities or other real variables. A number of empirical papers have attempted to prove these effects in different settings. Opler and Titman (1994) investigate whether high-leveraged firms are more likely to experience performance losses in industry downturns than others. Chevalier (1995a, b) uses supermarket firms' data to study the effects of LBOs on real variables. Phillips (1995) and Kovenock and Philips (1995) relate capital structure to pricing decisions in concentrated industries, and more recently, Showalter (1999) finds evidence on the strategic use of debt in limited liability firms for manufacturing industries and Campos (2000) extends the analysis to Spanish data. Despite

all these studies, the empirical tests of the limited liability effect are not conclusive yet.

The main contribution of this paper is to study the effect of a firm's chosen legal form on its level of risk exposure, taking into account that both variables can be endogenously determined.[2] This is the so-called 'self-selection' problem, in the sense that firms make choices of belonging to one group or another on the basis of unobserved factors that affect outcomes, but are not due to the decision being evaluated. To address this issue, following Lee (1976), we estimate a switching regression model with endogenous switch. We extend Lee's model in two ways. First, we use panel data, which allows for time invariant unobserved firm-specific effects that can be correlated with the regressors. In other words, we will allow for fixed effects, which would be impossible in the cross-section context. The usual cross-section model imposes independence between individual effects and regressors, which, in a panel data context, leads to the more restrictive random effects model. In addition, there are two types of fixed effects models that we particularly consider here: a model in which selectivity only enters through the fixed effects and a model which incorporates more general selectivity effects. We compare the results from these two models with those from a random effects one. In addition, since any firm's performance is also conditioned by its overall characteristics (activity sector, size, age, location), these elements are also included in the comparison between the two types of legal forms. Our empirical results show that, for a given capital structure, there is a significantly different behavior between both types of firms. Specifically, once the endogeneity between legal form and risk exposure is taken into account, we confirm the presence of the standard overinvestment problem only in the limited liability firms.

The rest of this paper is structured as follows. Section 2 presents a general model that shows why real behavior across firms differs according to their owners' liability status. To illustrate this idea with an example we translate it into a standard labor market partial equilibrium framework where, for a given capital structure, limited liability firms tend to assume more risk than their unlimited liability counterparts. More risk is defined in terms of choosing a lower capital-labor ratio and a lower expected labor productivity, since it will be proved that this implies higher output variance. Section 3 carries out an empirical analysis of this model to test our hypothesis about the different behavior of firms according to their liability status. Section 4 summarizes the main results.

2 A model of limited liability and risk in real decisions

In this section we introduce a simple theoretical framework that relates a firm's liability status (defined by its legal form, according to each country's corporate laws) with real decisions in the labor market made to maximize expected operating profits in a static setting. The model will be developed in two steps. We will first outline the general relationship between the limited or unlimited liability statuses with the

[2] Our dataset does not allow us to explicitly model the firms' initial choice of legal form. Turnover, tax advantages and administrative requirements are usually called for as explanatory variables.

risk attitude of the firm's owners. Then, as a particular example of this relationship, we will relate a firm's risk attitude with its hiring decisions in a neoclassical, partial equilibrium, labor market.

2.1 Limited liability and risk attitudes

When a firm is under unlimited personal liability (usually a single-owner firm) there is no difference between the proprietor's earnings and the market profits generated by her firm. By definition, the firm is part of the entrepreneur's personal estate and she cannot make distinctions among its elements. The owner, by itself or via debt, provides the funds needed to keep the firm in operation, then real decisions are made in order to maximize (expected) profits and, finally, at the end of any period, positive net earnings automatically increase her personal wealth, whereas negative earnings automatically decrease it.

This rent allocation is completely different when the firm is a corporation with limited liability. In this case the owners (namely, shareholders) are only entitled to a share of profits and to certain control rights to appoint a manager or a board of directors, who intends to maximize (expected) profits on their appointers' behalf.[3] Positive net earnings imply a payoff to the owners (dividends), but negative ones are not translated in the same way into their wealth. By law, losses are limited to the shareholders' initial contribution so that their personal estate is no longer open to unsatisfied creditors.

This asymmetry is hampered by corporate law in most countries, introducing different incentives for real decision-making depending on the firm legal status and liability. To see this, let $E[u(\tilde{W})]$ be the firm's owners' expected utility, where, as usual, $u(\cdot)$ functional form defines their risk attitude with respect to final net wealth. Let us assume the owners are initially risk neutral, so that $u(\cdot)$ is linear, and therefore by construction:

$$E\left[u(\tilde{W})\right] = u\left[E(\tilde{W})\right]. \tag{1}$$

Variable $\tilde{W}$ represents any period stochastic net wealth earned by the firm, given by the difference between operating profit ($\tilde{\pi}$), which depends on the firms' operating decisions, and payments owed to external creditors (D). Then, the owners' net wealth at the end of any period will be a transformation of $\tilde{W}$, that is, $\tilde{W}_U = \tilde{\pi} - D$ for unlimited liability firms, or $\tilde{W}_L = \max\{\tilde{\pi} - D, 0\}$ for limited liability ones.

In general, we can write $\tilde{W}_j = g_j(\tilde{\pi} - D)$, with $j = U, L$; where $g_j(\cdot)$ functional form now defines the owners' risk attitude with respect to net operating profits. Note that $g_U(\cdot)$ is linear, so that initial risk neutrality does not change for unlimited liability firms, whereas $g_L(\cdot)$ is convex, so that limited liability firms become risk-lovers with respect to profits. This result confirms the hypothesis advanced by Stiglitz and Weiss (1981) that limited liability protection is associated with riskier

[3] Since we intend to focus on the limited liability effect, in this simple formulation we ignore managers-owners conflicts. For simplicity, it is also assumed that no dividends are retained in this single-period world.

entrepreneurial activity. In a more recent paper, Asplund (2002) generalizes this idea to the study of risk-aversion in any oligopoly models.

The change in the owners' risk attitude with respect to the operating profits modifies the firm's real decision when intending to maximize them. This result can be formally proved by noting that (1) is equivalent to:

$$E\left[u\left(g_j\left(\tilde{\pi}-D\right)\right)\right]=u\left[E\left(g_j\left(\tilde{\pi}-D\right)\right)\right],$$

which becomes $E[u\left(g_U(\tilde{\pi}-D)\right)]=u[E(g_U(\tilde{\pi}-D))]=u[g_U(E(\tilde{\pi}-D))]$ for unlimited liability firms because $g_U(\cdot)$ is linear. Thus, by defining the composite function $f_U=u\circ g_U$, it results that in this case

$$E\left[f_U\left(\tilde{\pi}-D\right)\right]=f_U\left[E\left(\tilde{\pi}-D\right)\right],$$

and the firm's owners are also risk neutral with respect to operating profits. Similarly, for limited liability firms, expression (1) is equivalent to

$$E\left[u\left(g_L\left(\tilde{\pi}-D\right)\right)\right]=u\left[E\left(g_L\left(\tilde{\pi}-D\right)\right)\right],$$

with $u[E(g_L(\tilde{\pi}-D))]>u[g_L(E(\tilde{\pi}-D))]$ after using Jensen's inequality and the fact that $u'(\cdot)>0$. Hence,

$$E\left[f_L\left(\tilde{\pi}-D\right)\right]>f_L\left[E\left(\tilde{\pi}-D\right)\right]$$

where $f_L=u\circ g_L$, and the firm owners become risk lover in profits.

Note that capital structure plays a crucial role in these relationships, since the amount of debt implicitly defines the bankruptcy probability faced by a firm and, consequently, the extent to which owners under limited liability are protected. Under limited liability, more debt financing involves by definition a higher risk of failure, the cost of which is not borne by the firm's owners. Thus, the larger the debt level, the higher the change in risk attitude in favor of riskier decisions affecting operating profits.[4]

To include capital structure decisions in the above results it is required to extend the model to a previous stage in which firms first make financial decisions and then decide on the operating variables that ultimately determine the value of $\tilde{\pi}$. The model can be formulated as a two-stage game, where sub-game perfect equilibrium is achieved by backwards induction. Each firm first decide on its real variables for a given capital structure, and then select in the first stage the amount of debt that maximizes

$$E\left[u(\tilde{W})\right]=E\left[u(\tilde{\pi}(D)-D)\right].$$

The resulting payoffs are obtained by replacing this optimal debt level (say, D^*) into the second-stage net profit function. The exact value of D^* will depend on the type of strategic interaction among firms, as showed both by Brander and Lewis (1986) and Faure-Grimaud (2001).

[4] This relationship assumes that any other risk source that affects the bankruptcy probability (for example, aggregate risk at the economy-wide level) does not depend on the firm's capital structure.

2.2 Risk attitude and real behavior in the labor market

This subsection presents a simple labor market model that, within a standard partial equilibrium framework, serves to illustrate the idea that different liability regimes imply different real behavior among firms. The model, based on a representative firm with risk neutral owners, builds on Padilla and Requejo (2000). After choosing its legal form between a limited or unlimited liability status, our analysis starts by considering that the firm has access to a production technology which requires an investment of $I > 0$ to buy a certain level of capital stock for the period. The production function yields $X(N)$ units of output if N workers are hired in a competitive labor market at an exogenous known wage, w, the same for all firms.[5]

In order to finance the investment, which is larger than the owners' initial wealth, the firm issues debt with face value $D > 0$. Then, the product is sold in a competitive product market, at an *ex-ante* uncertain market price,$\tilde{\theta}$, which is assumed to be independently and identically distributed among firms according to a (twice-continuously differentiable) cumulative distribution function $F(\cdot)$. The proceeds of the sale minus the wage bill constitute the firm's operating profits, $\tilde{\pi} = \tilde{\theta}X(N) - wN$, which are used for debt repayment and shareholders' rewarding.[6]

In this short-run setup, the firm's problem is just to choose the number of workers to hire in order to maximize the owners' expected net wealth. We will show that the results of this decision depend on the legal status of the firm. Thus, for an unlimited liability firm, the objective function it intends to maximize is

$$W_U = E\left[\tilde{\pi} - D\right] = E\left[\tilde{\theta}X(N) - wN - D\right] \tag{2}$$

whose first order condition, given by $w = E[\tilde{\theta}X'(N)]$, implies, as usual, that the firm hires workers until their expected marginal productivity equals the market wage.

Alternatively, limited liability firms face a different problem. Since their owners are protected by law in case of financial distress, their expected net wealth is given by $W_L = E[\max\{\tilde{\pi} - D, 0\}]$, that is

$$W_L = E\left[\tilde{\theta}X(N) - wN - D \,\middle|\, \tilde{\theta} > \frac{wN + D}{X(N)}\right] \cdot \Pr\left(\tilde{\theta} > \frac{wN + D}{X(N)}\right), \tag{3}$$

where the last part denotes the non-default probability. Therefore, employment is chosen so that the market wage equals the expected value of the marginal productivity of labor conditional on the *ex-post* value of their claims to the firm's net wealth being positive. Hence, the first order condition is now

$$w = E\left[\tilde{\theta}X'(N) \,\middle|\, \tilde{\theta} > \frac{wN + D}{X(N)}\right], \tag{4}$$

[5] The production function also satisfies the standard technical conditions: $X(0) = 0$, $X'(0) > 0$, $X''(0) < 0$, $lim_{N\to 0}X'(\cdot) = \infty$, and $lim_{N\to\infty}X'(\cdot) = 0$.

[6] As pointed out by a referee, the amount of initial debt could be different for limited/unlimited firms since in a perfect credit market the lenders would anticipate each firm's behavior. A different debt level, however, does not change the predictions of the model.

stating that the employment level is now chosen by setting the market wage equal to a higher expected marginal productivity. For a given employment level, N, the set of states of nature (price realizations) considered by limited liability owners is a strict subset of the set of states considered by unlimited liability ones. Hence, by concavity of $X(\cdot)$, limited liability results in over-employment and inefficiency with respect to the unlimited liability case, where the firm simply maximizes its expected (unconditional) value.

The intuition behind these results, described in Sect. 2.1 above, is the same as in the well-known 'over-investment' problem of Jensen and Meckling (1976), which Brander and Lewis (1986) translated into the 'excessive risk shifting' of the limited liability effect. Because of this limited liability, the owners' *ex-post* valuations of the firm's results are convex so that they behave as risk lovers: among those projects with the same *ex-ante* value, they would prefer the project with more variability in its *ex-post* returns, thus assuming excessive risks. In our model, an increase in N constitutes a mean preserving spread in the distribution of the firm's *ex-post* returns, since it is immediate to see that

$$\frac{\partial E\left[\tilde{\theta}X(N) - wN\right]}{\partial N} = E\left[\tilde{\theta}X'(N) - w\right] = 0,$$

and

$$\frac{\partial \text{Var}\left[\tilde{\theta}X(N) - wN\right]}{\partial N} = 2\text{Var}(\tilde{\theta})X'(N) > 0.$$

Hence, a higher employment level (or, conversely, a lower capital-labor ratio) for a given capital structure always implies a higher risk exposure.

Finally, the model can be also completed introducing capital structure decisions. The procedure would be similar to that described above, using the value of the firm as a whole (V) to determine the optimal debt level issued by each type of firm in a previous first stage. Thus, by noting that the equilibrium levels of employment resulting from (2) and (4) are themselves functions of the debt level, $N_U^*[D]$ and $N_L^*[D]$, the debt-choice problem becomes the maximization of $V_j = E\left[\tilde{\theta}X[N_j^*(D)] - wN_j^*(D)\right]$, with $j = U$,L. The resulting first order condition,

$$\frac{dV_j}{dD} = E\left[\tilde{\theta}X'(N)\frac{dN_j^*}{dD}\right] - w\frac{dN_j^*}{dD} = 0,$$

confirms that debt plays a role only in limited liability firms since, according to (2), $w = E[\tilde{\theta}X'(N)]$ in unlimited liability ones. Note however that these additional calculations do not change the main relationship obtained in (4).

3 Empirical analysis

In this section, we empirically analyze the relationship between a firm's legal status and its risk exposure, according to the predictions of the theoretical framework in

Table 2. Sample description

Periods in the sample	Number of firms	Fraction (in %)
1993–1994 (2 years)	74	5.64
1992–1994 (3 years)	47	3.58
1991–1994 (4 years)	28	2.13
1990–1994 (5 years)	1164	88.65
Total	1313	100

Sect. 2. In particular, we estimate how risk exposure differs among Spanish firms, depending on their legal form, accounting for the fact that both variables could be jointly determined. To address this particular problem we make use of panel data techniques, which allow for time invariant unobserved firm-specific effects.

3.1 Data source and sample selection

We use data from the waves 1990-1994 of the *Encuesta Sobre Estrategias Empresariales* (*ESEE*, Spanish Firms' Strategies Survey) (see Fariñas and Jaumandreu 1995), which contains complete balance sheets data, employment and product market information for 2,595 Spanish manufacturing firms. Our sample is restricted to private firms with one of the following different legal forms: sole proprietorship (*empresa individual*) and firms with limited liability (*sociedad anónima*, SA, and *sociedad de responsabilidad limitada*, SL). These three legal forms represent more than 85% of all private firms in the Spanish economy. Public sector and government-controlled firms are not included in our sample, owing to their special profit-maximization behavior.[7] For the same reason, our final sample also excludes those firms that were taken over or experienced significant changes in their governance structures and firms that divested part of their business units during the sample period. Furthermore, in order to minimize the incidence of extreme observations, those firms that modified their legal status more than once in the five-year period considered have been dropped from the sample. After filtering the sample we end up with 1,313 firms that at least remained for two consecutive years in the *ESEE*. Table 2 shows that most firms in our sample (88.65%) stayed in it for the whole five-year period considered.[8]

In order to test the theoretical predictions about the different behavior of firms according to their liability status, we estimated the effect of having or not limited liability on two different dependent variables reflecting firm's risk exposure: labor productivity and capital-labor ratio. Labor productivity has been defined as the proportion of earnings before interest, taxes, amortization and the wage bill over total employment, whereas the capital-labor ratio is defined as the proportion of

[7] We also excluded other existing legal forms (labor-managed firms and partnerships) of minor importance in the Spanish economy because their different governance rules could possibly distort our results.

[8] In order to retain as many observations as possible, the unbalanced sample design has been preferred to a balance design. Furthermore, deleting those observations which are not represented in all five years would introduce a sample selection bias (see Pedersen et al. 1990).

Table 3. Overview of variables and summary statistics (standard deviations in parenthesis)

Variable	Description	Mean (limited liability)	Mean (unlimited liability)
Size	Number of employees	198.32 (523.6)	17.73 (15.14)
Export/Import	Dummy for exports or imports	0.63 (0.48)	0.24 (0.42)
Age1	Dummy for age of the firm between 0–5	0.18 (0.38)	0.11 (0.31)
Age2	Dummy for age of the firm between 6–20	0.42 (0.49)	0.45 (0.49)
Age3	Dummy for age of the firm > 20	0.39 (0.48)	0.43 (0.49)
Control	Dummy for coincidence between owner and manager	0.43 (0.49)	0.84 (0.36)
Quote	Dummy for quoting in the Stock exchange	0.03 (0.16)	0
Capital	Dummy equals 1 if firm is capital intensive	0.67 (0.46)	0.60 (0.49)
Debt	Total debt/Total Assets	0.57 (0.24)	0.44 (0.29)
Loc1 (rich regions)	Dummy equals 1 if the firm is located in Baleares, Cataluña, Navarra, Madrid, La Rioja	0.43 (0.49)	0.38 (0.48)
Loc3 (poor regions)	Dummy equals 1 if the firm is located in Andalucía, C. La Mancha, Extremadura	0.15 (0.35)	0.26 (0.44)
Loc2	Dummy equals 1 if the firm is located elsewhere	0.42 (0.49)	0.35 (0.48)
K/L ratio	Capital-labor ratio	5089.07 (76.05)	2047.58 (32.15)
Productivity	Labor productivity	4184.86 (29.6)	2709.60 (33.42)

fixed assets over total employment. Limited liability has been defined as a dummy variable taking the value 1 if the firm is SA or SL, and 0 otherwise.

The explanatory variables used in the estimation can be classified into two groups: variables relating the capital structure ratio, and variables representing several descriptive characteristics of the firm. In the first group we include the ratio of total debt to total assets. The potential endogeneity of this variable will be properly taken into account below. In the second group we included a set of dummy variables reflecting the size and age of the firm, if there is coincidence between managers and owners, if the firm is capital intensive, if it is quoted in the stock exchange and if the firm exports or imports. To complete the model specification, we have included time dummies to control for business cycle effects, sector dummies to control for industry-wide effects and localization dummies.

Definitions and summary statistics for the main variables are presented in Table 3. It can be observed that firms with limited liability hire a larger number of workers than firms with full liability. This result is not surprising since, by law, there is a requirement on the number of employees (or indirectly, the turnover size – see Table 1), in order to create a limited liability corporation. These firms also have higher labor productivity and capital-labor ratio.

3.2 Econometric models

We consider panel data models that allow for firms' specific effects, which are either assumed to be independent of the explanatory variables (random effects), or

allowed to be correlated with the explanatory variables (fixed effects). Our starting point is the following equation system:

$$\begin{aligned} d_{it} &= \mathbf{1}(\delta' x_{it} + u_{it} \geq 0) \\ y_{i0t} &= \mu_0 + \beta_0' x_{it} + \eta_i + \varepsilon_{i0t}, \quad \text{if } d_{it} = 0 \\ y_{i1t} &= \mu_1 + \beta_1' x_{it} + \eta_i + \varepsilon_{i1t}, \quad \text{if } d_{it} = 1 \end{aligned} \tag{5}$$

where the indices i and t refer to firm i in period $t (t = 1, \ldots, T)$; d_{it} is a selection dummy representing the firm's legal form choice, which is 1 for limited and 0 for unlimited firms; x_{it} is a vector of explanatory variables; y_{i0t} and y_{i1t} are continuous variables measuring risk exposure for limited and unlimited liability firms, respectively. Of the two variables, y_{i0t} and y_{i1t}, one is realized and the other is latent. Finally, η_i is an unobserved firm-specific time-invariant effect and $(u_{it}, \varepsilon_{i0t}, \varepsilon_{i1t})$ are the error terms. β_1, β_0 and δ are vectors of unknown parameters, whereas $\mathbf{1}(\cdot)$ stands for the usual indicator function.

3.2.1 Random effects

In a random effects model we assume that $u_{it}, \varepsilon_{i0t}, \varepsilon_{i1t}$ and η_i are normally distributed and η_i is independent of the x_{it} vector. Therefore, consistent estimates of the parameters can be obtained by pooling each wave of data (i.e., each cross-section). Thus, we can drop the t-subscript and include the random effects into the error terms, which then become $(u_i, \varepsilon_{i0} + \eta_i, \varepsilon_{i1} + \eta_i)$. Subsequently, the relationships in (5) could be estimated by ordinary least squares (OLS) techniques on the pooled data if the error terms $u_i, \varepsilon_{i0} + \eta_i$ and $\varepsilon_{i1} + \eta_i$ are assumed to be independent of the variables in x_{it}, or by instrumental variables (IV) if one of the x (in our case, debt) is allowed to be endogenous. However, if $d_i$and $y_i$are jointly determined, these methods provide inconsistent estimates of the parameters. Therefore, in order to consider the simultaneity between risk exposure and liability choice, we can use standard estimation techniques for a cross-section endogenous switching regression model.

A detailed analysis of this type of models is given in Lee (1976). Lee's approach consists of two steps. The first one is to estimate the pooled binary choice selection equation by maximum likelihood (a *probit* model). The second step requires estimating the risk exposure equations, taking into account the selectivity bias and the potential endogeneity of debt variables. Selection is accounted for by adding extra regressors, which can be seen as correction terms. These correction terms are functions of the index $\delta' x_{it}$, where the δ parameters are replaced by their first round estimates. For the case of exogenous regressors, OLS estimates with the correction terms added as additional regressors, lead to consistent estimates of the parameters. Potential endogeneity of debt can be accounted for by using IV (with its lagged values as instruments) instead of OLS in the second step. Moreover, since normality of the errors is assumed, exclusion restrictions are not required. More details on this estimator have been included in the Appendix.

3.2.2. Fixed effects

The panel structure of our data allows us to relax and test some implicit assumptions in the cross-section or pooled data analysis. Specifically, the firm specific effects

can be treated as time-invariant nuisance parameters, which therefore allows for correlation between fixed effects and regressors. In this case, we explicitly include the time period in the notation. Estimation is carried out taking differences between periods t and $t-1$ in Eq. (5) in order to drop out the fixed effects. The assumptions regarding the error terms of the differenced model will determine the exact method of estimation.

If we assume that no selection bias is present after differencing, standard panel data estimation procedures can be used. Under the assumption of strict exogeneity of the explanatory variables, consistent estimates of the parameters can be obtained by OLS regression of the first differenced model, whereas IV on the differenced model should be applied to account for the potential endogeneity of debt. In these cases, there is no reason to estimate the auxiliary selection equation and only the risk exposure equation needs to be estimated. This corresponds to the assumption that possible selection effects on the risk equation only enters through correlation between η_i and $(u_{i1},\ldots, u_{iT})$.[9]

A more general model is one in which selection not only enters through the fixed effect, but selectivity effects remain even after first differencing. In that case, we estimate a switching regression model for N firms observed T consecutive time periods. Therefore, this model accounts for the self-selectivity problem, as well as other forms of time-invariant unobserved heterogeneity. A two-stage estimation procedure adding a selectivity correction in the differenced equation yields consistent estimates of the parameters. In this case, the selectivity terms are calculated in a first step estimating the selection equation for each year separately. As in the previous case, we can use OLS or IV in the second step depending on the assumption about the exogeneity of debt (see Appendix for details).

3.3 Results

In this section we report the estimates from the different models described above. Our basic motivation is to examine two considerations: endogeneity of the legal form choice and the impact of controlling for correlated time invariant unobserved heterogeneity.

Results on the selection equation are presented in Table 4. In the first column we present the probit estimates based on the pooled data for the five waves, which are used to calculate the selection correction for the random effects model. In the remaining columns we include the estimates of the selection equation for each of the waves separately, which are used to calculate the selection correction for the fixed effects model. The results for the five waves are quite similar to each other and the estimates based on the pooled data are always in range of the estimates based on the separate waves. Standard errors are lower that those for the five waves separately and all pooled estimates are significant at the 5% level. The conclusions do not change. We find that the probability of choosing limited liability increases with size. The export/import effect is also positive, while the age of the firm has a

[9] This assumption has been previously used in the study of Pedersen et al. (1990) on wage differentials between public and private sector.

Table 4. Legal form choice (selection equation)

Independent variables	Pooled, probit	1990, probit	1991, probit	1992, probit	1993, probit	1994, probit
Size	0.897	1.016	0.506	0.837	0.522	0.428
	(4.21)	(2.23)	(1.51)	(1.86)	(0.23)	(0.32)
Control	−0.966	−1.543	−0.761	−1.149	−1.044	−0.382
	(−10.32)	(−7.72)	(−4.12)	(−4.70)	(−3.90)	(−1.77)
Export/Import	0.801	0.994	0.839	0.779	0.693	1.046
	(9.26)	(4.51)	(4.57)	(4.08)	(3.47)	(4.63)
Age2	−0.376	−0.097	−0.317	−0.550	−0.333	−0.732
	(−3.25)	(−0.39)	(−1.37)	(−1.99)	(−1.19)	(−2.02)
Age3	−0.860	−0.822	−0.729	−1.002	−1.005	−1.183
	(−6.83)	(−2.89)	(−2.85)	(−3.31)	(−3.40)	(−3.10)
Loc1	0.293	0.289	0.279	0.457	0.343	0.091
	(2.89)	(1.22)	(1.35)	(2.00)	(1.37)	(0.34)
Loc2	0.188	0.283	0.208	0.363	0.135	−0.133
	(1.90)	(1.19)	(1.00)	(1.65)	(0.58)	(−0.52)
Year 1991	0.285					
	(2.50)					
Year 1992	0.398					
	(3.39)					
Year 1993	0.586					
	(4.80)					
Year 1994	0.632					
	(5.09)					
Constant	2.930	3.289	2.813	3.247	7.977	7.771
	(9.95)	(5.20)	(5.32)	(5.59)	(10.07)	(11.49)
Log-Likelihood	−673.97	−126.37	−159.67	−138.115	−117.44	−104.79
N^o of observations	6,221	1,164	1,192	1,239	1,313	1,313

Dependent variable: Dummy equals 1 if the firm has limited liability and 0 otherwise. Sector dummies included. Figures in parenthesis are t-ratios.

negative effect. As expected, being the owner and the manager of the firm decreases the probability of limited liability. Regional dummies imply that limited liability is higher in other regions that in the poorest ones, where individual firms are more likely. Estimates based on the pooled data include time dummies for each wave. The estimates for the time dummies show that the probability of choosing limited liability increases over the sample period considered, ceteris paribus.

Results on the risk exposure equations are presented in Tables 5 and 6, which contain the results for the random effects and fixed effects models without and with correction for selection. The estimated standard errors take into account heteroskedasticity. In all cases, the debt endogeneity possibility has been considered, being instrumented with its lagged values.[10] The models are estimated on the unbalanced sample of 1,239 firms that were observed over three or more periods. The reason is that in order to account for the possible debt endogeneity, for the random effects models we use lagged values of debt as instruments (lagged one

[10] The cases without and with time and sector dummies were tested. Since these dummies turned out to be insignificant, we only report the estimation results without them.

Table 5. Risk exposure estimates. Random effects

	Productivity		Capital-Labor ratio	
	Pooled IV	Pooled switching, IV	Pooled IV	Pooled switching, IV
Limited	1.344 (3.80)	−10.618 (−2.34)	0.612 (0.64)	−6.483 (−2.33)
Total debt/Total assets	−2.131 (−3.97)	−1.546 (−2.50)	−2.817 (−2.06)	−2.093 (−4.75)
Control	−0.638 (−3.66)	−0.200 (−1.07)	−2.344 (−5.72)	−1.254 (−5.55)
Export/Import	0.637 (3.21)	0.627 (2.59)	−0.116 (−0.24)	−0.447 (−0.13)
Age2	−0.205 (−0.81)	0.310 (1.19)	−1.751 (−1.47)	−0.047 (−0.13)
Age3	−0.028 (−0.10)	0.822 (2.61)	−0.941 (−0.73)	−1.093 (−0.15)
Loc2	−0.188 (−1.0)	−0.018 (−0.08)	0.635 (1.18)	0.498 (2.47)
Loc3	0.265 (0.72)	0.486 (1.21)	0.385 (0.50)	0.920 (1.88)
Size	1.242 (4.44)	0.614 (2.07)	2.459 (3.81)	0.885 (1.83)
Quote	0.468 (0.73)	6.315 (4.16)	6.178 (1.59)	0.920 (0.40)
Capital	0.899 (6.34)	0.815 (5.35)	5.187 (16.44)	3.931 (21.71)
Constant	3.071 (6.13)	14.015 (3.03)	6.099 (3.69)	9.994 (3.38)
$\sigma_{1u} - \sigma_{0u}$		9.869 (6.81)		7.281 (5.95)
AdjustedR^2	0.2601	0.3337	0.2953	0.3475

Number of observations: 3,595. Figures in parenthesis are t-ratios. In IV estimation Total debt/Total assets in $t-1$ and $t-2$ are used as instruments.

and two periods), which requires three successive observations of each firm.[11] In the fixed effects models, the inclusion of first differenced explanatory variables makes debt dated $t-1$ a not valid instrument. Therefore, debt dated $t-2$ is used in this case as instrument to obtain consistent estimates under the assumption of debt endogeneity.[12]

3.3.1. Random effects estimates

Table 5 reports the results from the pooled data without and with selection correction. The first two columns correspond to the labor productivity dependent variable and the last two ones correspond to the capital-labor ratio dependent variable. We considered cases in which debt is assumed to be exogenous and it is allowed to be endogenous. We tested exogeneity of debt by means of Hausman-type tests, based on the difference between pooled OLS and IV estimates both for the model which treats limited liability as an exogenous variable and for the model which accounts for selectivity. The realization of the test statistics ranges from 20.24 – 43.73, which is always higher than the critical value of a χ^2 distribution with twelve and thirteen degrees of freedom respectively at 5%. We thus only report the estimation results accounting for the endogeneity of debt. Standard error of debt is higher when it is instrumented and its coefficient is lower in absolute value, although always negative. Regarding the remaining variables, our conclusions do not change with respect to the models that consider debt as an exogenous variable.

Pooled IV (2SLS) estimates show that firms with limited liability have higher labor productivity and capital-labor ratio than the rest of firms, although the latter is not statistically significant. This result seems to contradict our theoretical predic-

[11] Since debt does not play any role in the selection equation, observations with missing information of debt lagged two periods are also used in the selection equation.

[12] The use of additional debt lags does not change the results, whereas reduces the number of observations.

tions. However, once the endogeneity of the legal form choice is accounted form, we find that the risk exposure is significantly lower for firms that enjoy limited liability. This result is consistent with our theoretical prediction about the overinvestment problem associated with limited liability. The gap between the two types of estimates shows the importance of accounting for unobserved characteristics that might affect the risk exposure choice but are not due to the legal form adopted.

To test the hypothesis that simultaneity does exist, we test $\sigma_{1u} - \sigma_{0u} = 0$. We find that this coefficient is significant, which implies that simultaneity does occur. Moreover, a very important issue concerns the sign of these covariances. As pointed out by Trost (1981), if self-selection is based on comparative advantage, that is, if all firms who are faced with the choice between two regimes choose the regime which yields a maximum value, then the expected relationship between the covariances is $\sigma_{0u} < \sigma_{1u}$ and σ_{0u} and σ_{1u} can have any signs. If $\sigma_{0u} < \sigma_{1u}$ it means that the expected unlimited result (in terms of risk exposure) of the unlimited firms will be greater than the expected result of the unlimited firms if they were to have limited liability. Furthermore, it will also be true that the expected limited result of the limited firms will be grater than the expected result of the limited firms if they were to have unlimited liability (see Appendix for a detailed discussion of this point). In our case, this expected relationship holds both for the productivity and capital-labor ratio equations. So the estimates are consistent with the comparative advantage hypothesis.

3.3.2 Fixed effects estimates

Estimation results for the fixed effects models are included in Table 6, both under the assumption that legal form is exogenous (first differences estimates), and allowing for its endogeneity (switching regression of the first differenced model). As in the random effects estimates, estimation both under the assumption that debt is exogenous (OLS on the differenced model) and allowing for its endogeneity (IV on the differenced model) has been performed. Again, Hausman-type test comparing these two leads to rejecting exogeneity in all cases except in the models for the capital-labor ratio equation.[13] Therefore, in these cases debt has not been instrumented. In general, as in Table 5, the effect of accounting for the debt endogeneity is that estimated parameters are somewhat smaller in absolute value and the standard errors are higher.[14]

We observe that, in all cases and according to our theoretical predictions, there is a negative effect of limited liability on the risk choice by the firm, although no significant effect is found with regards to the capital-labor ratio dependent variable. Moreover, relative to the rest of estimates, the first differencing estimates show a downward bias (in absolute value) in the coefficient of limited liability. This result is unsurprising, since the first differencing estimator controls for correlated unobserved heterogeneity, but in doing so we would expect it to introduce biases due to lack of strict exogeneity of the legal form explanatory variable. Again, the null hypothesis that there is no correlation between the disturbances in the risk

[13] In this case, the value of the χ^2 with twelve degrees of freedom is 13.15, with a *p-value* of 35.81%.

[14] When debt is instrumented we obtain a negative effect of this variable on the capital-labor ratio equation, although this effect is non significant.

Table 6. Risk exposure estimates. Fixed effects

	Productivity		Capital-Labor ratio	
	First differencing, IV	Switching, IV	First differencing	Switching
Limited	−3.342 (−5.89)	−3.733 (−2.04)	−0.571 (−0.26)	−0.705 (−0.50)
Total debt/Total assets	−0.313 (−1.43)	−2.300 (−2.87)	1.235 (2.18)	1.926 (2.30)
Control	−0.153 (−1.57)	−0.306 (−2.50)	−0.038 (−0.17)	−0.334 (−2.05)
Export/Import	0.073 (0.56)	0.273 (1.71)	−0.215 (−0.73)	−0.196 (−1.11)
Age2	−0.141 (−0.85)	−0.361 (−1.51)	0.329 (0.82)	−0.023 (−0.14)
Age3	−0.224 (−0.83)	−0.319 (−0.85)	0.692 (1.14)	0.076 (0.24)
Loc2	0.739 (1.20)	0.067 (0.07)	0.626 (0.44)	−0.050 (−0.16)
Loc3	0.778 (1.16)	0.202 (0.42)	1.421 (0.72)	0.627 (1.79)
Size	−2.828 (−7.97)	−2.647 (−2.40)	−3.213 (−4.18)	−0.007 (−0.03)
Quote	−0.446 (−1.01)	0.878 (5.21)	−0.927 (−1.03)	0.878 (0.58)
Capital	0.159 (1.42)	0.018 (0.15)	1.522 (5.58)	1.073 (10.21)
$\sigma_{1u} - \sigma_{0u}$	–	9.772 (2.45)	–	2.172 (1.53)
AdjustedR^2	0.1099	0.1554	0.0984	0.1215

Number of observations: 3,595. Figures in parenthesis are t-ratios. In IV estimation Total debt/Total assets in period $t-2$ is used as instrument.

exposure equations and the selection equation (that is, $\sigma_{1u} - \sigma_{0u} = 0$) is rejected, and the models are consistent with the comparative advantage hypothesis, albeit the evidence for the capital-labor ratio model is weak.

To test the assumption of no correlation between the firm specific effects and the explanatory variables, we perform a Hausman test based on the difference between the random effects and the fixed effects estimates in Tables 5 and 6. The resulting values for the test statistics is at least 238.89. This exceeds the critical χ^2_{11} and χ^2_{12} values at conventional significance levels, indicating that the random effects panel data model that does not allow for correlation between firm specific effects and the explanatory variables is misspecified.

Regarding the comparison between fixed and random effects estimates that account for self-selection, it turns out that the estimates of the coefficients are upward biased in absolute value when correlated fixed effects are not considered. Comparing the results from the last columns in Tables 5 and 6, we can see that the failure in controlling for fixed effects overestimates the negative effect of limited liability in the risk exposure of the firms.

4 Conclusions

The main contribution of this paper has been to illustrate an empirical relationship between firms' legal status and their real behavior. For that purpose, we extend the usual link derived from the standard theory of risk exposure borne by the firms' owners to an empirical study that highlights several facts about Spanish firms' legal form and its connection with their real activity.

Consistent with the hypothesis we derived from a theoretical model based on the limited liability effect, we have empirically showed that firms under limited liability have significant lower labor productivity and lower capital-labor ratio than firms

under unlimited liability. That is, we observe the standard overinvestment problem associated to the limited liability status. However, we only obtain this empirical result when we specifically account in our regressions for the endogeneity between legal form and risk exposure and/or for existence of unobserved heterogeneity.

We have estimated a switching regression model for panel data, which has enabled us to take into account the self-selection bias as well as other forms of time invariant unobserved heterogeneity. Our results indicate that the legal form choice is endogenous to the risk exposure adopted by the firm. Our analysis, using panel data information, also reveals the importance of accounting for unobserved time invariant specific effects correlated with the explanatory variables: our overall conclusion is that standard models with random effects and models which only allow for selection through the fixed effects, are too restrictive. Finally, we have identified two types of bias not previously addressed by the literature: (i) a downwards bias induced by the exogeneity assumptions of the legal form choice; and (*ii*) an upwards bias due to ignoring time invariant firm effects which are correlated with the explanatory variables.

Appendix

Here we discuss some details of implementing the estimators which take selection into account, discussed in Sect. 3.

Random effects. The random effects model for one cross-section can be written as

$$\begin{array}{ll} y_{i0} = \mu_0 + \beta_0' x_i + v_{i0}, \, if & d_i = 0 \\ y_{i1} = \mu_1 + \beta_1' x_i + v_{i1}, \, if & d_i = 1 \end{array} \tag{A.1}$$

where $v_{i0} = \varepsilon_{i0} + \eta_i, v_{i1} = \varepsilon_{i1} + \eta_i$ and $E(v_{i0}) = E(v_{i1})$ = 0. Compared to the notation in Sect. 3, the time index t is omitted and the random effects are incorporated into the error terms, which are independent of x_i. Variables y_{i0} and y_{i1} indicate the risk exposure outcome if d_i equals 0 or 1, respectively. Hence the effect of having limited liability for firm i will be given by the difference y_{i1}–y_{i0}. It measures how the risk exposure would vary with the legal form if legal form were not self-selected, but exogenously assigned. It is now useful to rewrite previous equation as follows

$$\begin{aligned} y_i = \mu_0 + (\mu_1 - \mu_0) d_i + \beta_0' x_i + (\beta_1 - \beta_0)' x_i d_i \\ + (v_{i0} + (v_{i1} - v_{i0}) d_i) \end{aligned} \tag{A.2}$$

Taking conditional expectations, and since $E(v_{i0})$= 0, we have:

$$\begin{aligned} E\left(y_i | x_i\right) = \mu_0 + (\mu_1 - \mu_0) E\left(d_i | x_i\right) + \beta_0' x_i \\ + \left(\beta_1 - \beta_0\right)' x_i E\left(d_i | x_i\right) + g(x_i) E\left(d_i | x_i\right), \end{aligned} \tag{A.3}$$

where $g(x_i) = E\left(v_{i1} | x_i, d_i = 1\right) - E\left(v_{i0} | x_i, d_i = 1\right)$.

From (A.3) it is clear that the problem with OLS estimation is that $E(v_{i0}|x_i, d_i = 1) \neq 0$ and $E(v_{i1}|x_i, d_i = 1) \neq 0$ because of the self-selection. Therefore, the OLS regression of y on d gives inconsistent estimates of the parameters. In order to obtain the true causal effect of d on y we specify a reduced form *probit* for d, that is, $di = \mathbf{1}(\delta' x_i + u_i \geq 0)$, where v_{i0},v_{i1} and u_i are assumed to have a tri-variate normal distribution with mean zero and covariance matrix:

$$\Sigma = \begin{pmatrix} \sigma_0 & \sigma_{01} & \sigma_{0u} \\ & \sigma_1 & \sigma_{1u} \\ & & 1 \end{pmatrix}.$$

The estimation by maximum likelihood methods of the previous model could be very cumbersome, since it involves the evaluation of multiple integrals. For that reason, following Lee (1976), we use a simple two-stage estimation method, which gives estimates that are consistent. Since $g(x_i)$ is unobservable, what we have to do is to obtain the expected values of the residuals v_{i1} and v_{i0}. The assumption of joint normality allows us to write[15]

$$E(v_{i1}|x_i, d_i = 1) = \sigma_{1u} \frac{\phi(\delta' x_i)}{\Phi(\delta' x_i)},$$

and similarly for v_{i0},

$$E(v_{i0}|x_i, d_i = 1) = \sigma_{0u} \frac{\phi(\delta' x_i)}{\Phi(\delta' x_i)},$$

where ϕ and Φ are the density function and the distribution function of the standard normal evaluated at $\delta' x_i$. Then, we can write Eq. (A.3) as a regression model:

$$\begin{aligned} y_i = \mu_0 + (\mu_1 - \mu_0)\Phi_i + \beta_0' x_i \Phi_i \\ + (\beta_1 - \beta_0)' x_i \Phi_i + (\sigma_{1u} - \sigma_{0u})\phi_i + \xi_i, \end{aligned} \tag{A.4}$$

where $\phi_i = \phi(\delta' x_i)$, $\Phi_i = \Phi(\delta' x_i)$, and $E(\xi_i) = 0$. The two-stage estimation procedure consists of (i) using the *probit* model we get maximum likelihood estimates of δ, and (ii) using these, we get estimated values of ϕ_i and Φ_i. Thus, regressing y_i on a constant, x_i, ϕ_i and Φ_i and the interaction variables $x_i\Phi_i$ we get consistent estimates of $\sigma_{1u} - \sigma_{0u}$ and the rest of parameters.

Since we have more than one cross-section, we estimate the parameters in the random effects panel data model by pooling each wave of data and applying the previous estimation technique to the pooled data. The estimation of the selection equation is also based on the pooled sample, including time dummies as additional regressors.[16]

Note that one of the parameters of main interest for us is $(\mu_1 - \mu_0)$, that is, the differential effect of the dummy variable indicating the legal form. Moreover, in the previous specification the effect of x varies among firms with different values for d.

[15] See Maddala (1983) and references therein for details.

[16] Time dummies were also included in the risk exposure equation, but these turned out to be insignificant.

Estimation of Eq. (A.4) allows us to test which coefficients are different in $\beta_1$and β_0. Since some of the interaction terms $x\Phi$ may be insignificant, this procedure enables us to implicitly impose restrictions on the equality on some coefficients between the regression coefficients in the two regimes.[17]

The identification of the parameters of the model relies on the distributional assumption about the process generating risk exposure and legal form outcomes. That is to say, assuming that the disturbances are distributed tri-variate normal is enough to identify the model and it is not strictly necessary the presence of a regressor in the legal choice equation that does not affect the risk exposure variable.

The interpretation of the covariance terms σ_{1u} and σ_{0u} plays a crucial role in the discussion of selectivity bias. For that purpose, it is useful to write Eq. (A.3) as

$$E(y_{i1}\,|x_i, d_i = 1\,) = \mu_1 + \beta_1' x_i + \sigma_{1u}\frac{\phi\,(\delta' x_i)}{\Phi\,(\delta' x_i)}, \tag{A.5}$$

and

$$E(y_{i0}\,|x_i, d_i = 0\,) = \mu_0 + \beta_0' x_i - \sigma_{0u}\frac{\phi\,(\delta' x_i)}{1 - \Phi\,(\delta' x_i)}, \tag{A.6}$$

As pointed out by Trost (1981), if firms choose the regime which is a maximum (comparative advantage hypothesis), the only necessary condition for consistency of the model is that $\sigma_{1u} > \sigma_{0u}$, but σ_{1u} and σ_{0u} can be either sign.[18] For example, one case might be that $\sigma_{1u} > 0, \sigma_{0u} > 0$ but with the additional restriction that $\sigma_{1u} > \sigma_{0u}$. Hence, if $\sigma_{1u} > 0$, this means that $E(y_{i1}\,|x_i, d_i = 1) > \mu_1 + \beta_1' x_i$ and $E(y_{i1}\,|x_i, d_i = 0) < \mu_1 + \beta_1' x_i$, that is, the expected productivity of those firms actually choosing limited liability is greater than $\mu_1 + \beta_1 x$, and the expected productivity of those who do not choose limited liability is less than $\mu_1 + \beta_1 x$. Similarly, if $\sigma_{0u} > 0$, then $E(y_{i0}\,|x_i, d_i = 1) > \mu_0 + \beta_0' x_i$ and $E\,(y_{i0}\,|x_i, d_i = 0\,) < \mu_0 + \beta_0' x_i$. Therefore, the limited liability group "dominates" in both productivity equations. However, since $\sigma_{1u} > \sigma_{0u}$, although those who choose limited liability are better than average in both limited and unlimited regimes, they are still better in limited than in unlimited,

$$E\,(y_{i1}\,|x_i, d_i = 1\,) > E\,(y_{i0}\,|x_i, d_i = 1\,)$$

Furthermore, it will also be true that those who choose unlimited are below average in both limited and unlimited regimes, but they are better in unlimited than in limited,

$$E(y_{i0}\,|x_i, d_i = 0\,) > E(y_{i1}\,|x_i, d_i = 0)$$

Note that estimating Eq. (A.4), using all observations on y, let us estimate $\sigma_{1u} - \sigma_{0u}$ directly. Thus, the estimation of (A.4) is more convenient than separate estimation of (A.5) and (A.6).

[17] In fact, in the empirical specification, we considered cases with and without different $\beta_1$and β_0. Since the differences turned out to be insignificant, we only report estimation results imposing $\beta_1 = \beta_0$.

[18] Note that the signs of the covariances are opposite from those presented in Trost (1981) or Maddala (1983) because the selection equation in this paper is written with a positive disturbance, and with a negative one in theirs.

Fixed effects. We can extend the previous approach to the case of fixed effects models, in which the time invariant unobserved heterogeneity among firms can be correlated with the explanatory variables. In order to deal with the endogeneity problem controlling for fixed effects, we consider a switching regression model for N firms observed T consecutive time periods. Using simultaneously more than one wave for estimation requires that we explicitly include the time period in the notation:

$$\begin{aligned} y_{it} = \mu_0 + (\mu_1 - \mu_0)\Phi\left(\delta' x_{it}\right) + \beta_0' x_{it} \\ +(\beta_1 - \beta_0)' x_{it}\Phi\left(\delta' x_{it}\right) + (\sigma_{1u} - \sigma_{0u})\phi\left(\delta' x_{it}\right) + \eta_i + \xi_{it}, \end{aligned} \tag{A.7}$$

If we were to assume that η is uncorrelated with each x,we could apply pooled switching regression estimators, as we covered in previous section. If η is correlated with any element of x,then the pooled estimator is biased and inconsistent. Therefore, we can take differences on Eq. (A.7) to eliminate the time-constant unobservable η:

$$\begin{aligned} \Delta y_{it} = (\mu_1 - \mu_0)\Delta\Phi\left(\delta' x_{it}\right) + \beta_0' \Delta x_{it} \\ +(\beta_1 - \beta_0)' \Delta x_{it}\Phi\left(\delta' x_{it}\right) + (\sigma_{1u} - \sigma_{0u})\Delta\phi\left(\delta' x_{it}\right) + \Delta\xi_{it}, \end{aligned} \tag{A.8}$$

which is just a linear model with selectivity correction terms in the differences of all variables. Similarly to the cross-section case, consistent estimates of the parameters can be obtained by a two-stage estimation procedure on Eq. (A.8). In this case, the selectivity terms are calculated in a first step estimating the selection equation for each year separately. Thus, these terms are differenced along with everything else. Interpretation of the coefficients of the model and the selectivity correction terms previously presented are also valid for the fixed effects model.

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